I. C. 6732 JULY, 1933

UNITED STATES BUREAU OF MINES
SCOTT TURNER, DIRECTOR

INFORMATION CIRCULAR

RECOMMENDATIONS OF THE UNITED STATES BUREAU OF MINES ON CERTAIN QUESTIONS OF SAFETY AS OF FEBRUARY 3, 1933

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THE MINE SAFETY BOARD

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UNITED STATES BUREAU OF MINES

RECOMMENDATIONS OF THE UNITED STATES BUREAU OF MINES ON CERTAIN QUESTIONS OF SAFETY AS OF FEBRUARY 3, 1933[1]

By the Mine Safety Board[2]

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1 The Bureau of Mines will welcome reprinting of this paper, provided the following footnote acknowledgment is used: "Reprinted from U.S. Bureau of Mines Information Circular 6732."

2 G. S. Rice, chief mining engineer, chairman.
O. P. Hood, chief engineer, mechanical division.
R. R. Sayers, chief surgeon.
D. Harrington, chief engineer, safety division.
C. W. Wright, chief engineer, mining division.

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NOTE:- The first 10 recommendatory decisions of the 25 reported in this paper were given in Information Circular 6091 (December 1928); these and the eleventh decision were included in Information Circular 6139 (May 1929) and, with the twelfth and thirteenth decisions, were given in Information Circular 6198 (November 1929). In this paper, reporting all the decisions to date, 25 in number, there is no essential difference in the first part of the explanatory text from the text of Information Circular 6198, which covered the first 13 decisions, other than an exception in the field of application of decision 12; but the second part is new, and relates to the last 12 decisions formulated by the Board and approved by the Director of the Bureau of Mines since the issuance of Information Circular 6198.

INTRODUCTION

Mining men and State officials in their efforts to make mining safer are confronted from time to time with various complicated questions. In recent years these questions have tended to increase with the use of mechanical appliances. Twenty-five years ago electricity had been used but little in mines; today there is practically no other means of transmitting power employed in American mines, except that in metal mines compressed air is used, chiefly for drilling and for operating small portable hoists. In coal mines there has been a great increase in mechanization, which has the tendency to concentrate the work of production in small areas, and to increase the local difficulties of ventilation, also it has intensified locally the hazard from coal-dust in bituminous and subbituminous mines.

The answers to the questions which arise are not always obvious, as is shown by the fact that even able, experienced men differ in their opinions of the best way to overcome a particular mining hazard. The difficulty of solving the problems is also demonstrated by the varying provisions in mine-safety rules, both in official regulations and in the rules of those mining companies that are endeavoring to do more than follow the letter of the law. Such differences of opinion as to the best way of meeting a difficult situation are often found within the same mining organization, and, similarly, varying opinions are held by different members of the Bureau of Mines staff.

In order to reduce differences of opinion and to obtain a generally acceptable decision on any question, a mine safety board was established on June 1, 1924, by the Director of the Bureau of Mines -

> ***to consider questions arising within any divisions of the Bureau that require a definition of the Bureau's collective opinion as to safety practices, safety devices, or safety methods for underground operations or open-pit mining. ..... The approved decisions shall form the basis of teaching and policy for the Bureau.

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The decisions so far made for public issuance relate chiefly to questions on which there have been the greatest differences of opinion and to the best method of meeting certain special or new dangers. Other decisions will be rendered from time to time. Recommendations of Bureau engineers have already been issued on many general mine-safety problems the answers to which are obvious or on which there is practical agreement among mine-safety men. These recommendations are contained in various publications of the Bureau, and those relating to coal-mine safety are discussed in a handbook entitled "Safety in Coal Mining,"[3] and in numerous other mine-safety publications of the Bureau.

The wording of the decisions makes their application largely self-evident, but a certain amount of additional explanation is here given as to the detailed purposes and reasons for which they have been formulated. All the points of practice covered by the decisions were brought out in a study of reports made for and by the Bureau of mine fires, explosions, and general accidents in mines. As previously mentioned, it was found that the different members of the Bureau staff were not always in agreement as to the best method to recommend for technical handling of a specific complicated problem. Such questions as affect fundamental policies of the Bureau on mine-safety technology are referred to the Mine Safety Board, the members of which attempt to reach a common opinion.

Whenever practicable, a tentative decision which has been unanimously reached by the Mine Safety Board is submitted to members of the Bureau staff at the stations and in the field. Their comments are considered and may lead to changes in the draft. The final draft is submitted to the Director of the Bureau; if the recommendation is approved it becomes the decision of the Bureau on the specific question involved.

The decisions formulated up to March 1, 1933, 25 in number, are presented in the order of their approval. The reasons are given for the formulation of each decision and the application of each when not obvious is explained.

Many of the decisions relate specifically to coal mining because of its numerous and special hazards due to inflammable gas and dust. Others apply especially to metal and other mineral mining and a few are particularly related to the driving of long tunnels. But so far as possible, the wording of the decision is general rather than specific and is made applicable to as many kinds of mining as possible.

The order in which the different decisions appear has no significance as to relative importance. The decisions were made as the specific question or questions to which they relate were submitted - generally by field representatives of the Bureau - to the higher officials of the Bureau.

Definition of terms "Permissible" and "Permissibility"

In the Bureau's efforts to increase safety in mines which require various materials, appliances, and methods of using them, there were devised certain tests and specifications which, if met, entitle the manufacturer to state that such essentials and appliances are approved by the U.S. Bureau of Mines and are "permissible" for use in mines under the limitations prescribed in the approval. This, in the case of machinery, apparatus, devices, etc., is indicated by an approval plate attached to the article and, in the case of explosives, may be printed on the wrapper.

Many of the "permissible" articles, such as miners' lamps, machinery, and appliances using electric power, and materials such as "permissible" explosives are of special use in underground workings having atmospheres which may become explosive by reason of the inadvertent presence of inflammable gas or coal-dust.

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3 G. S. Rice Safety in Coal Mining: Bull. 277 Bureau of Mines 1928 141 pp.

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Additionally, for example, permissible explosives must not produce, in the Bureau tests, more than a specified amount of toxic gas per unit of explosive; gas-testing lamps and devices must be accurate within specified limits as well as safe in use in explosive atmosphere; and breathing apparatus and gas masks must provide air for the wearer fit to breathe for a specified length of time.

"Permissible" has a recommendatory meaning. The Federal Bureau has no mandatory powers. The authority, if exercised, to compel the use in underground workings of permissible articles in place of unapproved ones, lies in the officials of the respective States.

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Decision 1, relating to miner's lamps in coal mines

The United States Bureau of Mines recommends:

1. In all coal mines the portable lamps for illumination be permissible, portable, electric mine lamps; and also

2. In places where fire damp or black damp is liable to be encountered, a permissible, magnetically locked, flame safety lamp for gas detection, or equivalent permissible device, be supplied to at least one experienced employee in each such place; and

3. Any employee before being supplied with a permissible flame safety lamp be examined by a competent official of the mine to assure the man's ability to detect gas; and

4. All coal mines whether classed as nongassy or gassy in any part, be supplied with magnetically locked, permissible, flame safety lamps, properly maintained and in sufficient number for all inspection purposes.

The recommendations were made for the following reasons:

Open lamps or so-called safety lamps of unapproved kind may cause fires or ignite fire damp and coal-dust, and therefore they should not be used in coal mines. Miners' electric lamps have been so improved in illumination, convenience, and safety, that it is no longer to be considered a hardship in mining to use a portable permissible electric lamp; in fact it is quite the reverse.

However, since no approved electric lamp shows the presence of methane or indicates oxygen deficiency, one experienced employee in every place where such conditions are liable to be found should be provided with a permissible flame safety lamp, or equivalent permissible device, to be used for testing.

Although a permissible flame safety lamp is safe if properly assembled and used, there is a possibility of its being a source of ignition of fire damp if the lamp is illegally opened in the mine or is dropped and the glass broken, or if the lamp is struck by a sharp point or is moved so rapidly as to cause flame to extend through the gauzes. Accordingly the use of the permissible flame safety lamp should be limited to gas testing in the hands of competent and experienced employees who can demonstrate with accuracy and safety the percentage of methane in the air in excess of 1½ or 2 percent. The flame safety lamp also gives information as to the sufficiency of oxygen in the surrounding atmosphere.

Other underground employees working or traveling in well-ventilated places should be provided with portable permissible electric lamps giving an excellent steady light; the good illumination which these lamps provide if maintained in proper condition tends to prevent accidents from falls and other hazards, and the equipment itself is free from the danger of igniting gas and coal-dust.

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Decision 2, relating to the kind of explosives to use in coal mining

In the interest of safety the United States Bureau of Mines recommends that for blasting in coal mines, permissible explosives, fired electrically, be exclusively used; and that as an aid to blasting, all coal which is feasible to cut, should be cut or sheared.

The foregoing decision has reference to the character of the explosives employed for blasting in coal mines. It does not preclude the use of other methods, devices and appliances for blasting in coal mines (see decision 12, p.19) which have been approved by the Bureau of Mines and placed on its permissible lists. One of the conditions of permissibility of explosives for use in coal mines is the use of electric detonators of standard make for firing them. Others are: Proper placing of the drill hole and the use of incombustible stemming material tightly tamped.

Nonpermissible explosives such as black blasting powder, including pellet powder, dynamite, and special explosives that will not pass the Bureau's tests for permissibility, readily ignite fire damp and coal-dust and have been the cause of hundreds of explosions. Complaint is sometimes made that permissible explosives are not efficient bêcause they cannot be efficiently used in "blasting off the solid"; this practice, however, is a highly dangerous one, and should not be used.

Where coal is properly undercut, sheared, or overcut, blasting can be done efficiently and safely with permissible explosive. The design of coal-cutting machinery has so improved that nearly every condition in mining can be met by selection of a suitable cutter and a suitable mining method. At present at least three fourths of the coal produced in the United States is cut by machines. It is claimed that in some coal beds blasting with permissible explosives following cutting makes a few percent more screenings than if black blasting powder is employed; even if the claim should be correct for special conditions the Bureau believes that no operator is justified in taking the chances of an explosion disaster by using a nonpermissible explosive.

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Decision 3, defining what the Mine Safety Board considers to constitute a nongassy, a slightly gassy, and a gassy coal mine

The United States Bureau of Mines believes that all coal mines are potentially gassy; but for purposes of administration in respect to prevention of explosions and fires, the Bureau recommends the following classification:

Class 1 Coal Mine: A practically nongassy mine in which inflammable gas in excess of 0.05 percent cannot be found by systematic search.

Class 2 Coal Mine: A slightly gassy mine in which –

(a) Inflammable gas has been found* but in amount less than 2 percent in still air in any active or unsealed abandoned workings; or

(b) Inflammable gas can be found, but in amount less than 4 percent, in some place from which the ventilating current has been shut off for a period of 1 hour; or

(c) Inflammable gas can be found** but in amount less than ¼ percent, in a split*** of the ventilating current; or

(d) Inflammable gas enters a split*** of ventilating current at a rate**** of not more than 25 cubic feet per minute.

Class 3 Coal Mine: A gassy mine in which inflammable gas is found in amount greater than specified for a class 2 coal mine.

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* By employing an approved flame safety lamp, with flame drawn low, or by employing an approved gas detector, or by sampling and analysis with an approved gas analytical apparatus.

** By sampling and analysis with an approved gas analytical apparatus, or by employing an approved gas detector.

*** If but one continuous ventilating current is employed in a mine this shall be considered a "split" for the purpose of this definition.

**** Determined by sampling, analysis, and ventilating-current measurement.

General Notes Regarding Decision 3

The inflammable gas found in coal mines is, with rare exceptions, methane. In coal-mining fields where natural gas is found below the coal measures (in lower geologic horizons) by deep wells which penetrate through or near to coal mine workings, there have been instances, fortunately of rare occurrence, of leakage from the well into the mine, which have led to explosions in the mine.[4] Natural gas is chiefly methane – almost always more than 85 percent methane – but it usually contains ethane, propane, and traces of butane; therefore, if the latter components are found with methane in mine air, it is an indication of leakage. The lower limit of explosibility of methane-air mixture when there is turbulance is 5 percent and of natural-gas-air mixtures with about 10 percent ethane and associated hydrocarbon gases is 4.6 percent. The limit therefore varies with the character of mixture.

To determine, under the foregoing specifications, the classification of a specific coal mine in respect to gas, it is advisable that systematic testing and sampling of the mine air in each split of the ventilating current be done at least three times in a period of not less than 72 hours. All tests and samples of the mine air, except one, should show an inflammable-

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4 Rice, G. S., Hood, O. P., and others, Oil and Gas Wells through Workable Coal Beds; Papers and Discussions: Bull. 65, Bureau of Mines, 1913, 101 pp.

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gas content less than the maximum limit of the class to which the mine has been or will be assigned. In other words, a tolerance of one test or analysis may be permitted to provide for a mistake or a very exceptional occurrence.

When a new mine is being opened in a coal field where existing mines are generally gassy, it is advisable to assume that similar conditions will be found in the new mine; the development and equipment of the mines should be based upon the expectation that it will be assigned to class 3.

There is no more disputed question than that covered by this decision as to what constitutes a gassy (or gaseous[5]) mine. Only a few State regulations give any specific directions for determination of gassiness other than that of whether or not approved flame safety lamps are required.

A coal mine is popularly spoken of as a "closed-light" mine or an "open-light" mine.

Repeated instances of explosion disasters caused by gas ignition in "open-light mines" have shown that the term is misleading and dangerous in its implication. Moreover, such a method of rating a mine as gassy is not satisfactory partly because there is such a great difference in other requirements - in ventilation, in use of electricity, etc. Also it tends to prevent the adoption of the "closed lamp" by many mine operators who do not like to admit that their respective mines are gassy; although this is not a good reason why the operator should not take maximum precautions, it is a practical consideration. The bureau's plan in this decision would get away from the indefiniteness and confusion by specifying in precise terms what it designates as a "nongassy," a "slightly gassy," and a "gassy" mine. The Bureau's specifications are founded on a study of thousands of analyses of samples of mine air submitted to the Bureau of Mines laboratory at Pittsburgh.

Although this decision specifically refers to defining the gassy or nongassy conditions of a coal mine, its provisions should also be applied to those metal mines and tunnels which encounter inflammable gas. Although such occurrences are relatively rare, serious explosions of gas have occurred in water-supply tunnels driven through shales, as at Cleveland, Ohio, and Milwaukee, Wis., and several disastrous explosions have occurred in tunneling in California. Gas explosions have also occurred in sinking shafts for salt in New York and Michigan and for potash in Texas, as well as in operation of other noncoal mines in several States.

5 Although the word "gaseous" is most generally used in the United States, "gassy" is considered by the Bureau as more accurate in meaning. Literally a "gaseous mine" would be one not excavating solid matter; whereas a "gassy mine" is one in which the presence of gas is incidental to the mining operation.

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Decision 4, relating to auxiliary fans or blowers in coal mines and coursing of air

In the interest of safety, the United States Bureau of Mines, recommends that auxiliary fans or blowers should not be used in coal mines as a substitute for methods of regular and continuous coursing of the air to every face of the mine.

The reason for this decision is the increasing use of auxiliary blowers, which in the United States are nearly always electrically driven, as a substitute for proper coursing of the air. Proper coursing should be done by laying out the mine with double or multiple parallel entries, slopes, or rooms, using regularly spaced cut-throughs or crosscuts to provide successive new air connections close to the faces being driven and then successively closing them by stoppings or doors in such manner as to leave only the inner cut-through or crosscut open for air circulation. In gassy mines, line brattices should be used in each entry, slope, or room, from the last open crosscut to the respective face. There is great danger in the use of auxiliary fans that fire damp will be accumulated by recirculation of the air and will be ignited by an electrical spark. Further, the auxiliary fan as commonly used is intermittently operated - that is, operated only when men are in the heading or room - and bodies of fire damp may collect during times when the auxiliary fan is stopped.[6] Use of electrically driven auxiliary blowers has resulted in a considerable number of explosion disasters.

The term "auxiliary fan" does not apply to a "booster fan." An "auxiliary fan" as here used is a temporary installation and takes only part of the air-current circuit[7] as distinct from a "booster fan" which is a more permanent installation through which is passed the whole particular circuit of air to increase its pressure (negative or positive) so as to overcome resistance, with the object of increasing the volume, and (or) forcing the air in adequate amount through distant workings.

The use of a "booster fan" is rarely justified. In most installations investigated there was recirculation of the air, and where this happens if methane is given off in the circuit there is a corresponding increase in gas content in the air circulated. Explosions have resulted therefrom. The best way, which is ordinarily sufficient, is to improve airways and (or) to install a more powerful surface fan to obtain adequate pressure and volume of circuits of air throughout the mine. A booster fan installation should be contemplated for ventilating a distant extension of a mine only where it is not practicable to put down a new shaft and when, after all has been done that is possible to improve the airways, the air pressure required would be so high as to prevent proper operation of the underground ventilating doors.

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6 The only justification for the use of an auxiliary fan in a properly ventilated coal mine is for emergency work, as in driving a crossheading in rock to make a connection with distant workings, and where it is too far to carry the air properly by a line brattice. In such use the auxiliary fan should be operated continuously 24 hours in the day, the fan and pipe frequently inspected, and the air in the face of the heading tested. It is safer that the fan be driven by compressed air, but if it is electrically driven the motor and switches should be of explosion proof type and an armored power conductor employed; especial attention should be given to thorough insulation of the wiring; and the vicinity further should be fireproofed to prevent the possibility of starting a mine fire from electrical breakdown or overheating of bearings.

7 Greenwald, H. P., and Howarth, H. C., Recirculation of Air and Mine Gas Caused by Auxiliary Fans used in Coal Mines: Trans. Am. Inst. Min. and Met. Eng., Tech. Pub. 110, vol. 76, 1928, pp 164-183.

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Decision 5, relating to the prevention of coal-dust explosions by rock-dusting

To prevent the propagation of mine explosions, the United States Bureau of Mines, recommends rock-dusting all coal mines, except anthracite mines, in every part, whether in damp or dry condition. It also recommends that rock-dust barriers be used to sectionalize the mine as additional defense; but these should not be regarded as a substitute for generalized rock-dusting.

NOTE: For detailed specifications as to the kind of rock-dust, amount to use, where to be applied and method of sampling and testing, see Bureau of Mines Serial 2606 and American Engineering Standards Committee "Recommended American Practice for Rock-Dusting Coal Mines" quoted in Bureau of Mines Information Circular 6030.

The rock-dusting method[8] of preventing explosions of bituminous-mine dust (anthracite dust was found not to propagate an explosion) has now been accepted by all the chief coal-mining countries throughout the world. It was recommended after exhaustive testing in the Bureau of Mines experimental mine in 1913. The method was officially approved by France about 1917. It was officially required by Great Britain in 1921, and in Germany in 1926.

The term "rock-dust barrier", referred to in the above decision, is used to designate an arrangement in a coal-mine passageway for holding a specific mass of rock-dust (the amount varying with the surrounding conditions at the location), either in a single container or a group of containers at or near the top of the passageway which on discharge will extinguish the flame of a coal-dust explosion that may arrive from either direction along that passageway. Many of the types of barriers that have been installed in mines have not been successful in tests in the Experimental Mine.

A series of tests of various types of barriers[9] was conducted in the Experimental Mine from 1927 to 1931, and as a result 13 barriers of specific design and dimensions are on the approved list for certain locations and conditions.

8 The suggested use of noncombustible dust to neutralize the coal-dust was proposed by William Garforth in 1891, and testing begun under his direction in 1908 at the Altofts Colliery Yorkshire England. In the United States, testing was begun under the Technologic Branch of the U.S. Geological Survey (later the Bureau of Mines) by G. S. Rice and associates in 1909.

9 Rice, G. S., Greenwald, H. P., Howarth, H. C., Tests of Rock-Dust Barriers in the Experimental Mine: Bull. 353, Bureau of Mines, 1932, 81 pp.

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Decision 6, relating to sealing all parts of a coal mine which cannot be kept well ventilated and inspected

In the interest of safety, the United States Bureau of Mines, recommends that in coal mines all entries, rooms, panels, or sections that cannot be kept well ventilated throughout or cannot be inspected regularly and thoroughly, or that are not being used for coursing the air, travel, haulage, or the extraction of coal, be sealed by strong fireproof stoppings.

In the past the question of sealing has been a much disputed one among mining men. Some have considered that it was highly dangerous to inclose areas in a mine which might fill with a body of gas. The Bureau agrees with this point of view, unless the stoppings are strong and fireproof; and by strength is meant sufficient to maintain the stoppings in place if there should be a heavy fall of roof in an empty or partly empty goaf, suddenly compressing the gas or a gas-air mixture.

On the other hand, the engineers of the Bureau find from extensive experience that in large room-and-pillar mines in which the pillars are either not extracted at all or not extracted for a long period, the old areas are not generally well ventilated and often cannot be inspected because of danger of falls, and that the lack of ventilation is inevitable from the enormous territory which may be opened. Furthermore, these regions act as places for accumulating dangerous dust as well as gas.

The Bureau believes that the ideal system of room-and-pillar coal mining is to take out only a small percentage of coal on the advance, generally less than 20 percent, and then to extract the pillars promptly on a systematic line of retreat for the whole mine or for a large panel, which may be considered equivalent to longwall retreating. Under such conditions there should be no need of sealing extensive areas of open unused workings when they can be properly ventilated.

Where the workings of a mine, whether it is a metal or coal mine, have been connected to an adjacent mine and after more or less extraction of the mineral in that part of the mine, the connecting workings are not tightly closed, strong fireproof doors or stoppings should be erected in such connections at or near the boundary of the mine. The objective of this is to prevent fire or fumes entering from one mine to the other. In the case of coal-mine workings which have been connected, these stoppings should not only be fireproof but should be strong enough to resist the pressure of a gas or dust explosion. Explosion tests made by the Bureau of Mines on the strength of stoppings[10] indicate that a plain concrete slab acting as a flat arch when properly keyed into the ribs and floor, probably is the most practicable form of construction for a fireproof stopping strong enough to resist an explosion of ordinary degree of violence.

In erection of barrier-pillar stoppings which subsequently may be subjected to a high hydraulic pressure through abandonment of the adjacent mine workings and their filling with water, a release to avoid high-water pressure should be provided. This might be an inclined pipe extending down into a water-filled sump on the inby side of the stopping, thus furnishing a water seal to prevent escape of gas into workings in active operation.

10 Rice, G. S., Greenwald, H. P., and Avins, S., Concrete Stoppings in Coal Mines for Resisting Explosions: Bull. 345, Bureau of Mines, 1931, 63 pp.

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Decision 7, relating to the carrying of "intake" and "return" air currents in separate shafts, slopes, or drifts

In the interest of safety, the United States Bureau of Mines, recommends:

1. That the main intake and main return air currents in mines be in separate shafts, slopes, or drifts.

2. That the main intake shaft lining be of fireproof construction and there be a minimum amount of inflammable material in or adjacent to the shaft.

The recommendations in this decision are applicable to any kind of underground mining. Bureau of Mines engineers engaged in mine recovery operations during or following fires in coal and metal mines have experienced great difficulty in restoring ventilation and coping with hazardous conditions caused by placing of the "intake" and "return" currents, separated only by a partition, in the same mine opening. Even if the partition is fireproof and remains essentially intact, the smoke and fumes at the bottom of the shaft or slope will almost inevitably work around into both compartments. Also entrance to either compartment at the surface may be made impossible by flame or smoke.

If a strong explosion in a coal mine reaches a shaft in which a partition separates the intake and the return currents, the partition, even though made of concrete, is sometimes blown out because of the unbalanced explosion pressures in the separated compartments of the shaft.

Generally the two compartments in the same mine opening have been used because they were convenient and possibly reduced the initial expense of opening the mine, but such considerations should have no place in the development of a mine, the lifetime of which may be many years.

A fireproof lining in the main intake shaft is recommended to provide a safe means of exit in the event of an explosion or fire. In the greatest mine-fire disaster that has occurred in this country, in which 259 men were killed, the fire igniting the lining of the intake shaft short-circuited to the return shaft and thus prevented the escape of most of the miners.

The best practice today is to have at least three shafts or other openings with fireproof lining and to have the main hoisting shaft nearly neutral, with just enough of a fresh-air intake split to keep it properly ventilated.

It is advisable that there be a distance of at least 200 feet, or as much more as required by State regulations, between the intake shaft and the return shaft and that in this space and (or) immediately adjacent to the shafts, no structures of combustible material should be built or electrical transformer erected or combustible material stored.

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Decision 8, relating to definitions used in coal-mine ventilation regulations, but which may also be applied to ventilation in metal and other mines

The United States Bureau of Mines recommends that in mine ventilation the following definitions be used:

1. The term "intake air" and the term "return air" without qualifying adjectives shall be used only to define mechanical movement of the air respectively in an inward or outward direction with reference to the mine as a whole or to any one group of workings.

2. When health and safety are concerned, the term "pure intake air" shall mean -

(a) Air which has not passed through or by any active workings, and (or)

(b) Air which has not passed through or by any inactive workings, unless these are effectively sealed, and

(c) Air which is free from poisonous gas and by analysis contains not less than 20 percent oxygen (dry basis) and not over 0.05 percent of inflammable gas.

In the State mining codes there is much ambiguity as to the meaning of different mining terms. Therefore, as a prerequisite to the formulation of revised or new codes, it is advisable to employ specific terms.

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Decision 9, relating to the quantity and quality of air to be furnished in ventilating mines

The United States Bureau of Mines recommends in coal-mine ventilation practice the following specifications as to unit quantity and quality of air:

1. The quantity in cubic feet of pure intake air flowing per minute in any ventilating split shall be at least equal to 100 times the number of men in that split.

2. The quantity of air entering each unsealed place shall be at least 200 cubic feet per minute and as much more as may be necessary properly to dilute and carry away inflammable or harmful gases which may be present.

3. The air shall be made to circulate continuously to the face in every unsealed place into which an appreciable amount of methane enters.

4. The air in any unsealed place shall be considered unfit for men if it shall be found to contain less than 19 percent oxygen (dry basis), more than 1 percent carbon dioxide or a harmful amount of poisonous gas.

5. If the air in any unsealed place, when sampled or tested in any part of that place not nearer than 4 feet from the face and 10 inches from the roof, shall be found to contain -

(a) More than 1½ percent of inflammable gas, the place shall be considered to be in hazardous condition and require improved ventilation, and

(b) If more than 2½ percent of inflammable gas is found, the place shall be considered dangerous, and only men who have been officially designated to improve the ventilation and are properly protected shall remain in or enter said place.

6. If the air in the split which ventilates any group of workings contains more than 1½ percent of inflammable gas, these workings shall be considered to be in a dangerous condition and only men who have been officially designated to improve the ventilation and are properly protected shall remain in or enter said workings.

This decision, while primarily made for coal mining, contains specifications also applicable to other kinds of mining; it recommends provisions for the minimum quantity of pure air to each mine and in each active or unsealed place in the mine, the maximum allowable percentages of poisonous and inflammable gases, and the amounts of these which are so dangerous as to call for the withdrawal of men from the respective parts of the mine.

The first provision calls for the customary State regulation for a minimum of 100 cubic feet of air to be furnished to every man, but as measured in each ventilating split instead of, as in common practice, measuring at the foot of the intake shaft or entrance. It has been found that in some mines there is a leakage or short-circuiting of air at doors and stoppings so that sometimes only a small part of the intake air reaches the working faces.

The second provision calls for a minimum quantity of air current in not only each active working place but also every inactive or unsealed place.

The third provision calls for circulation of air in each place whether active or inactive, to the face or end, to ensure against accumulations of gas in any part of an unsealed place.

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The fourth provision specifies the requirements of air fit for breathing.

The fifth provision specifies a hazardous or dangerous percentage of inflammable gas in a body of air in an unsealed place, states where the tests are to be made to determine the limits of the volume of the gassy mixture, and also relates to the withdrawal of men from a place containing a dangerous percentage of inflammable gas.

The sixth provision specifies the percentage of inflammable gas in a ventilating split which constitutes such a hazard that miners should be withdrawn and kept out of that split until the dangerous conditions have been removed by improved ventilation.

The foregoing provisions for continuous circulation of air to the faces presuppose that mining officials obey the mining regulations of the respective State in which the mine under consideration is situated and in addition that they follow the best practices in coal-mine ventilation such as -

(a) Coursing air by means of double or multiple entries or other openings.
(b) Employing crosscuts between the double or multiple entries or other openings at specified intervals.
(c) Erecting stoppings or doors in every crosscut except the one nearest the face in the respective entries or other openings.
(d) Employing the best type of stopping, which, according to the better State regulations, must be built of incombustible material in crosscuts of the main or more permanent openings.

The character of stoppings other than in the main-entry crosscuts is not usually specified in the State regulations, but it is good practice to use incombustible material - preferably massive concrete - for all main stoppings except those for temporary use. In room crosscuts, gob walls or dirt filling is usually sufficient if kept tight, or tight board stoppings may be used; but curtains should not be used except in connection with line brattices extending beyond the last open crosscut, because of safety and efficiency. Check curtains in the mouths of a group of rooms to prevent short-circuiting of the air current is proper practice but the curtains should be kept in good repair.

The character of the doors used for directing the ventilating current and their operation are specified in some of the better State regulations, but the necessity of having doors in duplicate or triplicate between the main intake and return of the whole current or main splits is not specified, although this is in accordance with the best practice. The Pennsylvania mining law requires that where there is a door on "any incline plane or road whereon haulage is done by machinery" an extra door shall be provided for use in case of necessity; also, wherever a principal door is placed, an extra door shall be provided to be used in case of necessity. (Art. IX, sec. 8, Pennsylvania Bituminous Mining Laws).

The character of the overcasts is specified in some of the State regulations, but the advisability of employing "overcasts" or "undercasts" in place of doors wherever practical to do so is not emphasized as it should be, except in the case of Pennsylvania State mining laws applying to certain conditions, as follows: "In every slope with workings on both sides, an overcast and an undercast * * * shall be provided as a passageway for the use of employees to cross from one side to the other" (art. VI, sec. 5); and in gassy mines, "the return air from each split where from 70 to 90 persons are employed shall be conducted by an overcast into the return airway, which shall lead to the main outlet" (art. IX, sec. 1); also, "in every mine all new air bridges, overcasts or undercasts shall be substantially built of masonry, concrete, or other incombustible material, of ample strength, or shall be driven through the solid strata" (art. IX, sec. 7).

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In gassy mines line brattices should be used in headings and rooms to carry the ventilating current close up to the face.

Ventilation regulators are a necessity to proper apportionment of the ventilating current in the different splits. Theoretically if the splits are laid out so that the resistance to the movement of the air in each is identical there would be no need of regulators, which cause a loss of power, but while their employment should be minimized by changes from time to time in the splitting of the air current, the irregular advance of workings in a mine of large production capacity necessitates some extent of use.

The number of men on any one split of air is specified in most State regulations; this number varies from 45 to 100 persons permitted to work in one continuous air current or split. With adequate ventilation as specified in this decision, based on the number of men and the inflammable gas content, 75 appears to be a conservative figure to adopt, where not in conflict with State regulations, for the number of men employed on one continuous air current.

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Decesion 10, relating to ways of escaping from a mine

The **United States** Bureau of Mines in the interest of safety in all underground mines, recommends:

1. That every underground mine shall have two or more ways of escape to the surface, so arranged and equipped that men can escape quickly

2. Such ways of escape shall be so separated by at least 50 feet of natural ground throughout their length that damage to one from any source shall not thereby lessen the effectiveness of the other as a means of escape.

3. (a) Where the way of escape is a shaft which is steeper than 45° from the horizontal, it shall have incombustible walls or lining and contain no fire hazard from the surface to the lowest level.

(b) Where the way of escape is a drift or slope which is inclined less than 45° from the horizontal, the incombustible walls, or lining, and freedom from fire hazard shall extend at least 200 feet from the entrance.

4. Where but one way of escape has incombustible walls or lining, it shall be the normal intake airway.

5. Not more than 10 men shall be employed in any part of a mine on any one shift until a second way of escape from that part has been provided.

Decision 10 is intended to apply to any kind of underground mine.

The first provision is one which is to be found in practically all State mining codes. Since the establishment of the Federal Government mine-safety work in 1908 there have been numerous accidents in places from which men were unable to escape because there were not adequate arrangements for their getting out quickly, as by hoist in a deep shaft, or because escape passages were not well timbered, free of debris, and ventilated by intake air currents. For recommedations regarding main intake and return air currents to be in separate shafts, slopes, or drifts and the main intake shaft lining to be of fireproof construction, see decision, page 12.

The second provision is to establish a minimum distance between ways of escape to insure that a fire or explosion which blocks one way would not at the same time make the other means of escape difficult or impossible of access. For recommended minimum distance between main intake and return shafts see page 12.

The third provision relates to making fireproof the shaft, drift, or slope used as an escapeway, the obvicus purpose of which is to prevent the respective linings from getting on fire and cutting off the escape of men in the mine.

The fourth provision is to insure that where only one escapeway is fireproofed, that should be used as the intake entrance of the mine. This provision is also covered in a different manner by the second clause in decision 7.

The fifth provision is to prevent the employing of any considerable group of men in any part of any mine where there are not two ways of escape, and limits the group to 10 men on any one shift exposed to a hazard, until a second way shall have been made by sinking shafts or slopes, or driving drifts or crosscuts from the surface or from other workings.

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Decision 11, relating to haulage and hoisting in coal mines with reference to the ventilation

In the interest of safety, the United States Bureau of Mines, recommends that in coal mines, haulage and (or) hoisting be kept in intake air as far as possible.

The advisability of this recommendatory decision has been indicated by many reports by Bureau of Mines engineers on mine explosion and fire disasters. Since the general introduction of permissible miners' lamps and permissible explosives in gassy and dusty coal mines, and since, on the other hand, the almost universal adoption of electricity in this country for underground machinery and haulage, the chief cause of explosions in recent years has been electrical. Methane accumulations have been ignited by electric arcs either at or near the working faces, in poorly ventilated places and (or) in return airways, and the resulting explosions, often small at the origin, have been spread disastrously by coal-dust. Although coal-dust can be neutralized by rock-dust as specified in decision 5, a small percentage of methane in the air greatly increases the hazard of ignition and propagation by coal-dust and may require so large an increase in the amount of rock-dust that for high percentages of methane in the air current of a gassy mine, effective rock-dusting may be exceedingly difficult to maintain.

The hazard of ignition of gas or coal-dust is greatly lessened if all machinery and equipment employed in coal mines are of permissible kind.

Trolley haulage, which is so generally employed, and other nonpermissible machines and hoists which cause electric sparks should never be used except in a positive current of pure intake air.

The fighting of mine fires may be especially difficult if the hoisting and haulage is not done in intake air.

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Decision 12, relating to methods of firing shots in coal mines

The United States Bureau of Mines extending Mine Safety Decision 2, recommends that for blasting either coal or rock in coal mines, permissible* explosives or equivalent permissible device be used exclusively, and in addition recommends that in blasting** -

1. Each charge shall be in a hole properly drilled and stemmed with incombustible material.

2. Each shot shall be fired separately by a permissible single-shot blasting unit, using an electric detonator or igniting equivalent of a kind specified by the Bureau for the particular permissible explosive or permissible blasting device.

3. Before and following each shot in gassy and slightly gassy coal mines, examination for gas shall be made with a permissible flame safety lamp or permissible equivalent*** and -

4. If more than 1½ percent of inflammable gas is found, in the quantity and by the method specified in Mine Safety Decision 9,**** the place shall be considered to be in a hazardous condition and before another shot is fired the gas shall be reduced by ventilation below the percentage and quantity specified in decision 9.

5. Each shot employing explosives shall be prepared and fired by or under the immediate supervision of a man having a state certificate as a mine examiner, fire boss, or foreman; and whenever conditions permit all other men than those authorized to prepare and fire shots shall be out of the mine when shot firing with explosives is being done.

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* Anything that has successfully passed scheduled tests and is officially approved by the United States Bureau of Mines is termed "permissible."

** Exception: This rule would not apply where shot firing is done electrically from the surface when all the men are out of the mine.

*** Mine Safety Decision 1 relative to permissible flame safety lamps or equivalent.

**** Decision 9, paragraph 5: If the air of any unsealed place when sampled or tested in any part of that place not nearer than 4 feet from the face and 10 inches from the roof shall be found to contain -

(a) More than 1½ percent of inflammable gas, the place shall be considered in a hazardous condition and require improved ventilation and -

(b) If more than 2½ percent of inflammable gas, the place shall be considered dangerous, and only men who have been officially designated to improve the ventilation and are properly protected shall remain in or enter said place.

This decision, as stated in its opening words, supplements Mine Safety Decision 2 (p. 6) which primarily recommended the use of permissible explosives. Since the time of issuing that decision, a blasting device has been tested by the Bureau of Mines and determined to be suitable for use in gassy and dusty mines and has been termed a "permissible blasting device." This instrument consists of a reusable steel cylindrical shell which is charged with highly compressed or liquefied carbon dioxide and contains a heating element to be ignited by an electric squib within the container. A firing circuit can be established only after inserting a bayonet-locked firing plug in the end of the container. Only a permissible single-shot blasting unit should be used for firing.

Permissible explosives are "permissible" only when used in the manner prescribed in the "Schedule of tests." This decision (12) specifies that permissibility requires the

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shot hole to be properly located with reference to the "burden" of the blast and that the explosive charge be stemmed with incombustible material. The charge should be fired by electrical detonator, using a permissible single-shot blasting unit, one shot at a time, except in firing electrically from the surface when all men are out of the mine, as is the practice in some of the mines of Utah and in certain other districts.

The rapid firing of a series of shots in coal mines by shot firers who may not have charged the shots, who proceed from place to place firing the groups of shots, and who do not make any inspections presents a great hazard. Where several shots are fired in one place, gas may be liberated and (or) coal-dust stirred into the air by the first shots, and a subsequent shot may ignite the dust and (or) gas, as has frequently happened.

Furthermore, if one or more of the shots in a face or pillar are what are termed "depending shots," it is impossible to foresee how much or how little coal is thrown out by the first blast, leaving too light a burden for the second blast or else so heavy a burden that it may cause a blown-out shot. No permissible explosive or blasting device so far tested and given permissibility is absolutely free under all conditions of use from the possibility of some external flame, and if there is inflammable gas in explosive proportions in an amount in excess of that given in clause 4 of decision 12, or if there is a dense heavy cloud of coal-dust present, ignition may occur which may lead to a disastrous explosion. Although this combination of circumstances is perhaps rare, it has occurred and may occur again if every precaution is not taken.

Special Conditions Which May Require Exceptions to Single Shot-Firing

Where more shots than one are to be fired in a working place of a mine it is possible that under some conditions special hazards may exist in firing shots separately and inspecting between shots; in such cases simultaneous multiple shot-firing may be allowable, when permitted by the respective State mining regulations. This condition may occur in steeply pitching workings or in working places where outbreaks of gas may be released by shot, or where the roof, draw slate, or coal is so friable that despite use of usual good timbering methods, falls are likely to occur after a shot, making it dangerous to inspect the roof and to connect the firing leads for the next shot. This possible exception making choice of a lesser hazard does not mean that the Bureau of Mines recommends simultaneous multiple shot-firing when it is at all practicable to fire safely one shot at a time with careful inspection for gas and roof conditions before and after each shot. When multiple shot-firing is necessitated by the conditions, it should be done by firing simultaneously with standard electric detonators. The use of fuse and (or) delayed-action detonators, so called, is dangerous because of the possibility that a delayed-shot may ignite gas or a coal-dust cloud thrown out by a previous shot.

No multiple shot-firing device for use in gassy coal mines under this exception has been approved by the Bureau of Mines at the time of completing this paper (May 1933), but an investigation is being conducted to determine its feasibility; meantime, when multiple simultaneous shot-firing is necessitated by the conditions, such available multiple shot-firing device should be selected as will give as low-tension current as possible for firing not to exceed six shots at a time, with duration of current of the smallest fraction of a second. Under no circumstances should the power lines be used in blasting when men are in the mine.

In section 1 of the decision (12) it is emphasized "properly placed" shot-hole being properly drilled and stemmed with incombustible material." This applies to blasting with a permissible device as well as with explosive.

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The only blasting device so far (May 1933) approved by the Bureau contains in addition to liquefied carbon dioxide a "heating element" which might, under certain conditions of imperfect stemming, or if the shot-hole intersects a crevice or joint plane in coal or rock, produce sufficient external heat to ignite coal-dust or inflammable gas. In fact, engineers of the Bureau have observed an "illumination" from shots with this blasting device. Moreover, the sudden release of high-pressure gas, whether it be carbon dioxide or other gas (or air recently tried in blasting devices as yet not tested by the Bureau) might, under exceptional conditions produce sufficient heat by adiabatic compression at some point in the shot-hole to ignite a methane-air mixture. Hence, the need of incombustible stemming for either blasting devices or explosives.

"Properly stemmed" means tightly tamped stemming. The necessity for this for explosives is well understood, but it has not always been understood to apply to blasting devices. Tight stemming is necessary not only to prevent issuance of flame but also to prevent violent ejection of the shells of the blasting device from the hole. A number of accidents have occurred in which men have been killed or severely injured by violent projection of the shell. In certain instances the shell has rebounded from a corner into a crosscut and caused accidents to workers. In one instance in an English mine, the shell was shot through the end of a steel mine car. Even if tight tamping of the stemming is done men should retire to a safe distance and out of the line of fire or rebound, to an adjacent working place. In Great Britain a post, sprag, or other suitable obstruction set up in front of the blast hold, is now required to prevent ejection of the shell in a dangerous manner. Such a method or an efficient shell anchorage within the hold seems advisable in addition to stemming.

Section 5 of decision 12 recommends that the men who fire the shots shall be certified men and that they shall know what each hole contains before firing it, either charging it themselves or having it charged under their immediate supervision. It also recommends as an additional precaution where the organization of the mine and other conditions permit, that shot-firing with explosives shall be done when all other men than those authorized to fire shot are out of the mine.

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Decision 13, relating to electrical equipment in coal mines which may become gassy

The United States Bureau of Mines recommends that when electricity is used in coal mines rated as gassy,* or whenever in any mine the atmosphere may become gassy:

1. Electrical equipment shall be permissible,**
2. Nonpermissible electrical equipment*** shall be used only in pure intake air,****
3. Electrical power shall be cut off whenever the air in the workings is in a dangerous condition,***** due to inflammable gas.

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* Decision 3 classifies coal mines on the basis of the specific amounts of methane found in the mine atmosphere. See also, decision 9.

** Anything that has successfully passed scheduled tests and is officially approved by the U.S. Bureau of Mines is termed "permissible."

*** Including trolley wires, trailing cable connections other than through permissible junction boxes, and power lines (except armored rubber-covered cables which meet the specifications of the National Electrical Code.)

**** Decision 8 defines "pure intake air."

***** Decision 9 defines the proportion or amount of gas in a mine working which shall be considered dangerous.

The alarmingly frequent explosions due to electrical ignition by electric arcs from trolley wires and bare power lines, that have occurred in coal mines, especially in recent years, make it highly important that electrical equipment should be "permissible" when used in any parts of a mine where gas is likely to be encountered. The Bureau in Mine Safety Decision 3 states that in its opinion "all coal mines are potentially gassy," but for purposes of administration in respect to the prevention of explosions and fires, it recommends their classification as nongassy, slightly gassy, and gassy.

Decision 9 states that if more than 1½ percent of inflammable gas is found in the air of a place, it is in a hazardous condition, and if more than 2½ percent is found, no men should remain in the place except those charged with the duty of improving the ventilation and who are properly protected, as by wearing permissible oxygen breathing apparatus and using approved gas indicators of dependability and precision.

If the gas inflow into a coal mine from the surrounding strata were constant and the workings and other conditions uniform, provisions for ventilation could be made, except under abnormally gassy conditions, that would practically insure against ever having a hazardous gas condition in that mine, except by breakdown of ventilating equipment. But none of the factors are constant; the gas inflow changes as the mine faces advance, new fissures carrying gas are encountered, large roof-falls occur which tap gas "feeders" or throw down gas collected in caved ground, and the mine workings are constantly changing in shape and conditions, all of which in turn affect the ventilating arrangements.

It is therefore the opinion of the Bureau that the maximum degree of safety from electrical ignition in coal mines would be obtained by using only permissible electrical machinery, and other permissible electrical equipment, including locomotives and underground hoists. The Mine Safety Board recognizes, however, the commercial difficulties of putting this

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recommendation into effect, as, for example, in nongassy mines and in the intake air of mines rated as gassy. Nevertheless, the Board is emphatically of the opinion that nonpermissible electrical equipment should not be used except where the atmosphere is as free from inflammable gas as is specified for "pure intake air" in decision 8, which calls for not over 0.05 percent of inflammable gas in "pure intake air." This view is also indicated in decision 11 "that in coal mining, haulage and (or) hoisting be kept in intake air as far as possible."

Power cables for underground use in coal mines classed as gassy have not as yet been covered by a Bureau of Mines schedule of tests for "permissibility." It is tentatively recommended that only those cables termed "armored cables" of the rubber-covered type constructed in accordance with the specifications of the National Electrical Code be used, and that the "armor shall be electrically continuous throughout and grounded." (Tech. Paper 402, p. 5.)[11]

Trailing cables also have not been covered by the Bureau of Mines schedule for permissibility. Until a permissible list for trailing cables is established by the Bureau, the users of permissible machinery should employ the trailing cables recommended for the specific permissible machinery. (Details of the general character, installation, protection, and inspection are given in Technical Paper 402.) In all places where inflammable gas might be encountered and permissible machinery and armored cable is used, the Mine Safety Board recommends that trailing cables should receive current through permissible junction boxes.

In gassy and slightly gassy mines there are great hazards in having trolley wires or unarmored power lines in headings and working faces beyond any open crosscuts. Such electric wires should not extend into rooms, longwall faces, or pillar workings, or beyond any continuously operated ventilating circuit which is not controlled by effective ventilating doors or stoppings. Curtains and loose gob stoppings or any stoppings or doors which allow air leakage should not be considered effective.

One of the greatest electrical hazards, especially in coal mines, is found where pumps with nonpermissible motors and connections and bare cables are used in workings either active or inactive, and especially where the pump has an automatic restarting device controlled from a distant switch. The pumps often are used intermittently and inspected only occasionally. Numerous disastrous explosions and fires have been caused by such pump installations. The hazard exists whether the pumps are in return air or nominally on intake air, as falls of roof may bring down gas or an open door may cause gas to accumulate. Where ordinary power lines are used instead of armored cables, explosions or fires may be started by an electric short circuit in power lines thrown down by a fall, or ignition may occur from sparking of the motor.

11 U.S. Bureau of Mines, Safety Rules for Installing and Using Electrical Equipment in Coal Mines: Tech. Paper 402, 1926, 21 pp. (Sponsored by the U.S. Bureau of Mines and the American Mining Congress.)

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Decision 14, clearance spaces for travel in haulageways, shelter holes, and location of trolley and other electrical conductors

In the interest of safety in coal mining, the United States Bureau of Mines recommends:

1. That in all haulageways, there shall be a continuous space for travel on at least one side of the trackway with a clearance of 30 or more inches from the nearest obstruction to the furthest projection of any moving equipment.

2. That any electric conductors other than armored cables, telephone, and low-voltage signal wires shall be placed on the opposite side of the haulageway from the traveling space.

3. That in all haulageways there shall be holes that may be used for shelter, suitably marked, unobstructed, and not over 60 feet apart on the traveling side, not less than 3 feet deep, 5 feet wide, and 6 feet in height or as high as the traveling space if that is less than 6 feet in height.

4. That at sidings of haulageways the tracks shall be so placed that there will be a space between them free from obstruction, at least 3 feet wide between the furthest projections of equipment moving or standing on the two tracks and where necessary because of conditions of roof support, this space may be regarded as a substitute for the traveling space, as provided in the preceding sections.

5. The provision of traveling space shall be as in (1) wherever practicable, otherwise the speed of haulage shall be limited to 3 miles per hour.

Accidents in haulageways due to switching and spragging, coupling, falling from trips, being run over, caught between car and rib, caught between car and roof, and runaway cars cause over one sixth of the total number of accidental deaths in coal mines and a correspondingly large proportion of total injuries. The group of haulage accidents is larger in the aggregate than any group of accidents other than those caused by falls of roof and coal.

In 1931 there were 240 lives lost in haulage accidents in the coal mines of the United States; this figure does not include those electrical fatalities - 33 in number - due to short-circuiting of the trolley wire. The objectives of this decision are to prevent men from being electrically shocked and to provide traveling space and refuge holes in haulageways.

State coal-mining regulations usually require shelter holes on haulageways to be made at intervals of 60 to 100 feet but none of the State regulations specify the minimum width of clearance space between the trackway and the rib or the nearest obstruction. Also, many of the State laws do not specify where trolley or power lines should be placed in the haulageway; the Bureau makes the definite recommendation (section 2) that they should be placed on the opposite side of the haulageway from the traveling space.

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Decision 15, wetting machine cuttings, the face, and tops of cars in coal mining

In the interest of safety in coal mining, the United States Bureau of Mines to lessen the coal-dust explosion hazard recommends that:

1. Machine coal cuttings be wet as the cutting is being done.
2. The coal face, and the working place 40 feet therefrom, shall be kept free of coal-dust by the use of water.
3. The top of loaded cars in the working place shall be wet.

Coal-dust is inevitably produced in the cutting, blasting, and loading of coal. The above recommendations are aimed at wetting, so far as practicable, the dust at the point of its formation in the working places and thus prevent it from rising, as a dry dust will do, into the air and being carried by the air current into adjacent places. This decision is not, except for an insignificant overlapping of methods to be used at the faces of the mine, in conflict with decision 5 which recommends rock-dusting of all coal mines in every part; this decision supports that recommendation because if a smaller amount of coal-dust is distributed around the mine, less rock-dust is required for coal-dust neutralization.

Recommendations 2 and 3, advocating wetting the coal face and tops of loaded cars, can best be effected by having water lines extending to each face and watering by hose, each face region being kept supplied with suitable hose.

These recommendations do not apply to anthracite mines the dust of which will not propagate an explosion.

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Decision 16, machine cuttings to be removed in coal mining

In the interest of safety in coal mining, the United States Bureau of Mines recommends that:

1. Machine cuttings be removed from the cut.
2. If the machine cuttings are of a character which would contribute to a dust explosion, they shall be sent out of the mine.

The purpose of having cuttings removed from the machine cut is primarily to prevent coal-dust from being blown around the working place in the blasting of coal and, secondarily, to obtain efficient blasting and possibly avoiding blown-out shots by making the cut free from cuttings which support the coal. The removal of the cuttings without unduly stirring dust into the air can be done if decision 15 is followed, by wetting the cuttings before removal.

Recommendation 2 applies to bituminous coal mining.

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Decision 17, lessening the formation and distribution of coal-dust in haulageways in coal mines

To lessen the formation and distribution of coal-dust in haulageways, the United States Bureau of Mines, recommends that in bituminous and lignite coal mines:

1. The mine cars should be constructed and maintained dust-tight.
2. The coal should be so loaded that it will not shake off in haulage.
3. The cars and loads should be so sprayed as to prevent dust being distributed along the haulageways.

The recommendations in this decision support those in the preceding Decisions 15 and 16. Although considerable dry coal-dust is always found at the working face even after watering, it is the falling of the coal from cars in haulage and the blowing of dust from the tops of loads by the air currents which are largely responsible for the wide distribution of coal-dust and extensive dust-explosion disasters.

Recommendation 1 calling for tight cars, is aimed at preventing the leakage of coal and coal-dust along the roadway through cracks in the car bodies and around loose-fitting gates. A large proportion of pit cars in the past, as well as at present, permit considerable leakage of coal along haulageways.

Recommendation 2 calls attention to a generally prevalent practice of loading cars high above the top rail of the car so that when the inevitable bumping in haulage occurs, the coal is spilled off, or the topped coal hits cross bars or a low place in the roof and gets knocked off. Much of this loose coal is ground to dust under the wheels of the cars.

The high topping of cars is usually an indication of insufficient car equipment or of inadequate haulage facilities from the working places. Any advantage of increased output from the individual working places by topping is probably temporary and is outweighed by having dirty roadways, a consequent liability to haulage accidents, and an increase of the dust hazard.

Recommendation 3 is aimed at preventing coal-dust on the tops of loaded cars and in empty cars from being blown off by the ventilating current, which is accentuated by the "wind" produced in high-speed haulage.

A recommendation in decision 15 requires that the tops of loaded cars in the working place be wet; recommendation 3 in this decision, No. 17, calls for automatic spraying of the cars at or near sidings, preferably at the entrance to sidings.

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Decision 18, superintendents and foremen of coal mines should have State certificates of competency

In the interest of safety in coal mining, the United States Bureau of Mines recommends that:

1. The foreman regularly in charge of underground operations and also any person who, in the absence of the foreman, may be placed in temporary charge should each have a certificate of competency from the State to act as mine foreman.

2. The superintendent or person in responsible charge of the mine, to whom the mine foreman reports, should have a certificate of competency from the State which should be issued upon a showing of underground experience for a period of time as long as that required for a foreman's certificate and upon passing an examination including all technical questions asked in the examination required of foremen.*

3. These certificates should expire after some stated period of time, such as 5 years, and should be renewed only after the applicant has again passed the examination required by the State.

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* Requirements for foremen's certificates will cover this provision.

Experience has shown that while foremen, or mine managers as they are termed in some States, must have State certificates, it is not always required that those who substitute or are in temporary charge have certificates of competency. This is particularly true of the position of mine superintendent, which in many instances is filled by a person who is not a mining man and yet is in real charge of the safety of the employees of the mine and therefore should be competent to direct safely and efficiently when emergencies arise, such as when by reason of fires or explosions the mine foreman may be entombed or unavailable. Further, where there is only a mine foreman or underground manager at a mine and perhaps no other employee with a foreman's certificate, the foreman may spend too large a proportion of his time on the surface when he should be underground directing his working shift. Mining laws in a few of the States which have lesser mining industries do not require certification of fire bosses, foreman, or superintendents. Therefore in these States there is no one officially responsible at a mine for its management, which is manifestly not a desirable condition so far as safeguarding the lives of mine workers is concerned.

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Decision 19, concerning internal-combustion engines in underground work

In the interest of safety, the United States Bureau of Mines recommends that:

1. Internal-combustion engines should not be used in any parts of mines and also should not be used in tunnels under construction because of the hazard of carbon monoxide in the exhaust gases, except -

(a) When the air current is more than 100 linear feet per minute and the toxic gases are always less than 0.02 percent in the air current.

(b) When the percentage of inflammable gas in the air current is less than 0.25 percent and (or) inflammable gas cannot be detected in any place by a permissible flame safety lamp.

2. Gasoline or other highly inflammable liquids should not be used for engine fuel in mines and in tunnels under construction because of the hazard of their transportation and use.

Many serious accidents have occurred in mines and tunnels through the use of gasoline locomotives, pumps, and underground hoists. In some instances these have been caused by explosion of the gasoline, either in filling the tanks of the engines or in transporting the gasoline underground. A few years ago a disastrous explosion occurred in a mine in the Sarer (France) when a barrel of benzine (gasoline) fell while being lowered in an upcast shaft, the vapor ignited in some unreported way at the surface, and the resulting explosion not only wrecked the surface plant but set fires underground.

There have been many instances of explosions and fires and many cases of suffocation from the exhaust fumes of gasoline locomotives, pumps, and engines in mines in the United States, so that many State laws or mining department regulations have forbidden the use of gasoline engines in mines. However, these State laws or regulations or orders do not in general specifically forbid the use of gasoline motors in tunnel construction.

In driving tunnels for water supply or for general mining purposes in several of the western States, gasoline locomotives (which are in some instances converted automobiles) or gasoline-driven trucks have been used, the exhaust gases of which have caused numerous cases of illness and asphyxiation among tunnel workers.

It has been supposed by many that there was little hazard in the use of gasoline locomotives or trucks in tunnels of large cross-section, but in such tunnels often there is an advance heading in which the locomotive under some circumstances may be used. In other cases the construction of the lining at more or less distance from the face requires extensive forms and staging, usually built of wood, which acts to restrict the ventilation and may bring about a dangerous concentration of inflammable or toxic gases. For example, a gasoline engine might produce locally a physiologically dangerous amount of toxic gases, and (or) if the strata give off methane, as has frequently occurred not only in coal mines but also in tunneling as in places in the Coast Range Mountains of the Pacific coast, an explosive mixture of methane might collect and might be ignited by sparks from the exhaust of the gasoline engine - hence the specifications in the decision requiring a positive adequate ventilating current in which the percentage of toxic gases or of inflammable gas shall never be more than the respective percentages specified.

Although in tunneling it is much safer and generally better to employ permissible storage-battery locomotives and permissible electric pumps and hoists, if the ventilation

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requirements are met and other precautions are taken it appears to be reasonably safe to employ Diesel locomotives which use a heavy nonvolatile fuel oil, whereas the use of gasoline or other volatile highly inflammable fluids as a fuel presents too many hazards of fire and explosion to be permitted underground in tunnel construction or in mines.

This decision does not refer to the use of steam-operated locomotives in mines and tunnels. Such equipment was formerly used extensively in mines in thick coal beds in the Pocahontas region of Virginia and West Virginia and also in tunnels that were being driven in different parts of the country, but as many accidents occurred from asphyxiation, steam-driven locomotives have not been used for many years except in a few isolated localities. An accident in which several men were killed by suffocation occurred recently in a mine tunnel in which a steam locomotive was used. Even though supposedly adequate ventilation for the tunneling operation might be provided, the steam locomotive would still present the hazard of fires by sparks or the dropping of hot ashes and hence should not be permitted in mines or tunnels under construction.

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Decision 20, relating to ventilation in the development and operation of tunnels, drifts, slopes, and shafts

In the interest of safety in underground mining, the United States Bureau of Mines recommends that:

> While driving tunnels or drifts and sinking or raising shafts or slopes, and also in their operation, there should be an adequate ventilating current wherever men work or travel.

Before starting a mining or tunneling development, plans and arrangements should be made for immediate installation of an adequate mechanical ventilation. Although under favorable conditions tunnels or drifts have been driven and shafts or slopes have been sunk many hundred feet while depending upon natural ventilation, in many instances the absence of mechanically produced ventilation has led to serious accidents. These have been due to inflammable, toxic, or unbreathable gas issuing from the strata, to deficiency of oxygen and most frequently to toxic gases from blasting. Various natural and mining conditions make it unsafe to drive a heading or sink a shaft even a short distance without a positive ventilating current produced by mechanical means.

Therefore, whether hazards are apparent or not at the time of beginning an underground development, adequate ventilating plans should be made and mechanical ventilating apparatus installed before starting. For the simpler shallow shafts or short slopes, steam or compressed-air jets placed in upcast ducts may be sufficient, but in all large undertakings, a reversible centrifugal fan of ample capacity for emergency use and with a good-sized air pipe or duct should be installed. In the more difficult developments, as in long tunnels making much gas, the use of double ducts for intake and return may be advisable, or at the very least the use of a pipe or tube of sufficient cross section to carry an ample air current not only to supply the human requirements of sufficient oxygen but also to sweep away toxic and inflammable gases produced in blasting and coming from the strata.

The dangers of insufficient ventilation in coal-mine developments, from accumulated gases and explosions thereof, are understood by experienced mining men, but the danger of encountering inflammable and toxic gases in tunnels driven through rock or unconsolidated material for water supply, mine drainage, or other purposes is not well known; numerous accidents, however, have demonstrated beyond question that gases in explosive or dangerous toxic proportions are likely to be found.[12] Also, there have been many instances of encountering inflammable and toxic gases in reopening old mines and in sinking shafts through sands, gravels or silt as well as through rock formations of different kinds.

12 Harrington, D., and Denny, E. H., Gases that Occur in Metal Mines: Bull. 347, Bureau of Mines, 1931, 21 pp.

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Decision 21, relating to protection of supporting posts in main haulageways, slopes, and inclined shafts

In the interest of safety in underground mining, the United States Bureau of Mines recommends that:

> In slopes or inclined shafts which are so steep that fallen material may roll or slide, and in main haulageways, posts supporting the roof or sides should be set in protecting niches in the wall. Where this is not practicable, substantial guard rails should be placed along the posts.

As stated in the decision, in slopes or inclined shafts which are so steep that the fallen material may roll or slide, whether these be haulage slopes or inclined shafts, posts supporting the roof or sides should be set in protecting niches or else placed on substantial side walls so that if a fall of roof occurs, the rocks displaced will not, in rolling or sliding, dislodge the legs of timber sets supporting the roof, which might bring down other falls. There have been instances where extensive falls have thus been caused and in certain cases have killed or entrapped men in lower workings.

Derailments of mine cars are likely to occur in any mine. Many derailments which have occurred may be classed as unavoidable because due to a fallen rock or breakage of rail or car wheel or other mechanical part, weaknesses of these types often not being dislosed even by careful inspection. But whether avoidable or unavoidable, serious following accidents may in many instances be prevented if posts, directly supporting the roof and (or) sides and the legs of framed sets, are so placed or recessed in protective niches in the sides of the haulageway that they will not be knocked out by derailment. This may not always be feasible in temporary haulageways but wherever practicable should be done in main haulageways, whether level or inclined; where not practicable, guard rails or continuous heavy planks should be placed along the posts and fastened securely to them in such manner that derailed cars will be fended off and not be likely to pull out the posts or the legs of timber sets.

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Decision 22, relating to sealing or guarding openings to mines under certain conditions

In the interest of safety in underground mining the United States Bureau of Mines recommends that:

1. All surface openings to underground workings not necessary for the operation of the mine or for escape, which are not adequately ventilated, timbered, and regularly inspected, should be kept securely closed to prevent unauthorized persons entering and surface fires from extending underground; and

2. All openings necessary for operation or escape should be guarded against the unauthorized entrance of persons.

During the time that mining has been done on a large scale in the United States, hundreds of lives have been lost and many million dollars worth of property has been destroyed through neglect to seal the surface openings of abandoned mine workings. Many of these accidents have been due to men entering unventilated workings to inspect without proper safeguards, and to trespassers entering to dig coal or other mineral and being suffocated by the deficiency of oxygen in the atmosphere of the mine, or poisoned by breathing air containing toxic gases such as hydrogen sulphide or carbon monoxide where there was a smouldering fire in the mine. Many children as well as men have entered abandoned workings or old shafts in a spirit of curiosity, and have been asphyxiated or killed or injured by falls of roof or by falling down a shaft.

The greatest loss of mining property and mineral reserves arising from leaving surface openings unsealed is due to fire. In many instances a small neglected fire has spread through great areas of workings.

One extensive fire in an old anthracite mine working is said to have started from dumping hot ashes into a hole at the outcrop. This fire spread through several hundred acres of old pillar workings, caused the abandonment of many houses on the surface above because of gases and fumes rising through cracks, and was not checked until it reached a solid coal barrier sufficiently deep below the surface to stop it.

Wherever beds of coal outcrop above the water level of the particular locality and there are unsealed openings, fires are liable to occur. The more general causes are spontaneous combustion in slack piles and surface fires, which extend into the mine opening. In some instances these surface fires have been started carelessly by persons igniting brush or building a small fire in the mine opening for heating, and doubtless in other cases the fires have been started maliciously. However, there have been many instances of strokes of lightning igniting brush or timber from which the fire has spread into a mine.

It is evident that the cost of sealing abandoned workings is insignificant as compared with the damage which may occur from fires. Besides the risk of property damage from leaving abandoned or suspended mines unsealed, many instances occur each year of men and children entering old mines and being suffocated.

The question arises as to the responsibility for such occurrences. If a mine of any size is to be abandoned, it is usual to take out the machinery and underground tracks. After that is accomplished the surface openings should be sealed by erecting strong brick or stone walls properly plastered, or else solid concrete stoppings. Where it is thought that the mine may be reopened, steel or concrete doors should be erected and effectively padlocked. In all cases the doors and frames should be of incombustible material.

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When it is known that a mine is to be definitely abandoned before the seals are erected it is advisable that the roof for some distance inside be blasted down.

There is another important advantage in sealing drift or slope openings into old mine workings in which the waters are acidic and from which water accumulates and overflows. It has been found by investigations of the Bureau of Mines that acidity of the mine water is largely stopped by excluding the air from the mine and thus preventing oxidation of pyrite, which is practically always found in coal strata. After sealing, the entrance of normal subsurface waters, which are alkaline, will flush out and (or) neutralize the acid salts already formed. The present condition of acid water running out of old coal-mine drifts in some parts of the country has presented serious problems of stream and river polution, notably in central and western Pennsylvania. In some instances the mine owners have been legally compelled to go to heavy expense for construction of diversion dams and tunnels.[13] Hence, the sealing of unused mine workings where it lessens the acidity of waters flowing from the mine has advantages besides those of safety and prevention of possible fire loss.

13 Leitch, R. D., A General Review of the United States Bureau of Mines Stream Pollution Investigation; Rept. of Investigations 3098, 1931, 7 pp.

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Decision 23, relating to checking men into and out of mines

In the interest of safety in underground mining, the United States Bureau of Mines recommends that:

Every underground mine should keep a record in a safe and quickly accessible place on the surface, which will show the time when each person goes into and when he comes out of the mine and which will also show, insofar as practicable, where he may be found while in the mine.

It is the experience of well-organized mining companies that it is an economic as well as a safety measure to have a record made, on a suitable form, of when each man enters the mine. It is advisable that this record include the probable place where the man will be working during his shift; there might be an exception to this in the case of foremen or inspectors or other workers who may be called upon to visit various parts of the mine. Entry should also be made on the record as to the time when each man comes out of the mine.

It is usual to have a record of some kind made by a clerk at or adjacent to the lamp room where safety lamps or electric lamps are issued. At some mines a man receiving a lamp is given a numbered metal check the duplicate to which is hung on the check board at the same time. When the man comes out of the mine he surrenders his lamp and check and the time is noted, or should be, on the record.

Where such records are kept, if a man should not come out of the mine at the end of his shift the unclaimed check would give warning of a possible accident to him and a search for him could be promptly and properly directed. If the mine were so unfortunate as to experience an explosion or fire, an inspection of the record would give knowledge as to those who might be in the mine and where they most likely could be located by the rescue crews. In some cases the checking system has been made ineffective because the check board containing the record was so located that it was destroyed by the force of an explosion in the mine, or because the record (check board) was cut off from access through being located in mine workings filled with smoke and fire gases at time of mine fire. For these as well as other reasons it is desirable that the record be kept in a safe as well as a convenient place.

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Decision 24, relating to guarding trolley and bare power lines

In the interest of safety in underground mining, the United States Bureau of Mines recommends that:

1. Trolley and other bare wires should be adequately guarded wherever the wire is less than 6½ feet above the level of the top of the rail;

2. In mines using loading chutes on one side of the haulageway, the trolley and other bare power wires should be placed on the opposite side and adequately guarded at the chute.

3. Trolley and other bare power lines should be sectionalized by electrical switches which can be safety handled, at the entrance to different parts of the mine; and

4. Trolley and other bare power lines should be adequately supported by strong, insulated hangers so spaced that if a hanger is missing the wires will not sag or shift and thus constitute a hazard.

Shocks and fatalities from electric power lines in mines have been one of the major classes of accidents in both metal and coal mines, especially in recent years; most of these accidents are due to men coming in contact with trolley lines and power lines on haulageways. Although it is advisable that separate passageways or manways for the travel of the majority of the employees be provided in which bare power lines are safeguarded so as to reduce the exposure of most of the employees to electric shocks, it is difficult to provide separate manways in all parts of the mine; hence the advisability of following the specifications for installation of trolley and bare power lines in the above decision. Many mining men seem to consider that guarding of bare power wires, including the trolley wire, at the main intersections or similar places where men pass under them is sufficient protection; but there have been hundreds of fatal contacts with unguarded bare power wires at points where haulage men have tried to couple cars or rerail them, or where the motorman or his helper for some reason or other have come in contact with the bare unguarded power wire. Numerous metal mines and several coal mines have installed and maintained guards for trolley wires throughout the trolley haulage roads and have been amply repaid by the resultant freedom from accidents caused by contact with the trolley wires.

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Decision 25, barrier pillars between adjacent mines

In the interest of safety in underground mining, the United States Bureau of Mines recommends:

1. That every mine contiguous to one or more mines in the same vein or bed should, so far as practicable, have separate ventilation, haulage, and escapeway systems, and the underground workings of each mine should be separated by a strong barrier pillar to prevent a fire or an explosion penetrating from one mine to another. Provision should be made to relieve excessive pressure of accumulated water on one side of the barrier.

2. In case mines already are connected and thereafter it is practicable to provide satisfactory separate ventilation, haulage, and (or) escapeway arrangements for each mine, a barrier pillar should be established and the openings which connect the mines should be sealed by strong, tight fireproof stoppings or pack walls.

3. The barrier pillar should be maintained intact until the workable mineral has been completely removed from the contiguous workings; then if permitted by the respective State requirements and property restriction, and if it can be done with safety, marketable mineral in the barrier should be extracted.

Many fires in metal mines or the gases and smoke from the fires have passed from one mine to an adjacent mine with disastrous results to life and property. In coal mines similar serious results have occurred from mine fires and explosions, the latter sometimes having even more disastrous results to life, than fires. These instances have been either because of the absence of barrier pillars or because the connections were unguarded by fire- and explosion-proof stoppings and doors.

Under the act of February 25, 1920, operating regulations to govern coal-mining methods and the safety and welfare of miners on leased lands on the public domain were formulated by the Bureau of Mines and issued by the Secretary of the Interior, 1923. Sections 104a and 104b which include essentially the recommendations in decision 25, also call for a lateral strength of stoppings to resist mine explosions having a pressure of at least 50 pounds per square inch on either side of the stoppings. Results of the tests made by the Bureau of Mines in conjunction with the Bureau of Standards and recommendations made for the construction of stoppings were published in Bureau of Mines Bulletin 345, referred to previously (p. 11).

Justifiable exception may be made to recommendations of sealing all connections through a barrier pillar to an adjoining mine when, under conditions which are liable to arise, there is need of maintaining an escapeway through the barrier pillar and adjoining mine, provided that adequate ventilation and timbering is maintained in the escape passages on either side of the barrier and also provided that steel or reinforced-concrete fire doors in sets of two or three are installed in substantial frames of steel and concrete. Additionally, in bituminous-coal mines, approved "rock-dust barriers"[14] for extinguishment of coal-dust explosions should be maintained in the escape passages on either side of the barrier pillar.

As regards removal of barrier pillars where there is not danger to property and lives, a Pennsylvania legislative act (1929) permits removal when approved by a special commission for each specific case.

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14 See footnote 9.

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